

Collaborative Engagement Experiment

Katherine Mullens^{a*}, Bradley Troyer^b, Robert Wade^b, Brian Skibba^c, Michael Dunn^d

^a Space and Naval Warfare Systems Center San Diego, 53560 Hull Street, San Diego, CA, USA 92152

^b U.S. Army Aviation and Missile Research Development and Engineering Center, Redstone Arsenal, AL 35898-5000

^c U.S. Air Force Research Laboratory, 104 Research Road Tyndall AFB, FL 32405

^d Science Applications Information Corporation, Bldg 4, Room 351, Eckel Street, Fort Benning, GA 31905

ABSTRACT

Unmanned ground and air systems operating in collaboration have the potential to provide future Joint Forces a significant capability for operations in complex terrain. Collaborative Engagement Experiment (CEE) is a consolidation of separate Air Force, Army and Navy collaborative efforts within the Joint Robotics Program (JRP) to provide a picture of the future of unmanned warfare. The Air Force Research Laboratory (AFRL), Material and Manufacturing Directorate, Aerospace Expeditionary Force Division, Force Protection Branch (AFRL/MLQF), The Army Aviation and Missile Research, Development and Engineering Center (AMRDEC) Joint Technology Center (JTC)/Systems Integration Laboratory (SIL), and the Space and Naval Warfare Systems Center - San Diego (SSC San Diego) are conducting technical research and proof of principle experiments for an envisioned operational concept for extended range, three dimensional, collaborative operations between unmanned systems, with enhanced situational awareness for lethal operations in complex terrain. This paper describes the work by these organizations to date and outlines some of the plans for future work.

Keywords: UAV, UGV, unmanned systems, collaborative behaviors, lethal operations

1. INTRODUCTION

Combat lessons learned indicate an urgent need for reconnaissance, early warning and security. Compelling logic infers that unmanned systems operating collaboratively could provide significant operational flexibility and soldier survivability in meeting this need. This collaborative capability, when combined with the ability for near real-time engagement of identified high value targets, offer prospects for immediate payoff to operational forces. For the purposes of this paper, *collaborative behavior* is defined as unmanned systems working together to accomplish predefined mission(s) with minimal human operator intervention. The main characteristic of collaboration includes the ability for unmanned systems to work as a team, command one another, pass information directly to each other, and make changes to their missions based on that information while being monitored by a human operator.

Few systems have operational requirements documents that specify collaboration, but all signs point to the need for this capability in the near future. There has been a significant increase in development of unmanned systems, each one utilizing a different control system. These unmanned systems will be integrated with manned units and eventually provide lethal engagement capabilities. There must be a technology focus that unloads the burden of low-level control away from the warfighter so that the focus can be on ensuring that the data received from and the capabilities provided by unmanned systems are effectively utilized in the accomplishment of the mission.

The Director of the JRP appointed AFRL, AMRDEC and SSC San Diego as the charter members of the Collaborative Engagement Experiment program. The overarching goal of CEE is to develop Joint technologies that will enable unmanned systems to perform collaborative behaviors while working to eliminate the creation of 'separate' solutions for each service. Research has been done at the university and individual lab level on unmanned systems collaboration, but one of the main goals of CEE is a Joint experiment using military-developed systems showcasing battlefield capabilities. This partnership helps the JRP to achieve its objective of providing increased warfighter capability and survivability with integrated and interoperable unmanned systems to achieve national security objectives. The results of these experiments will be utilized by all the services as their unmanned systems programs continue to mature.

* kathy.mullens@navy.mil; 1 619 553-3673; www.spawar.navy.mil/robots

There are several military programs in various stages of development that seek to capitalize on the growing developments and capabilities in the area of unmanned systems. The most prominent is the U.S. Army's ***Future Combat Systems (FCS)***. FCS is the Army's modernization program consisting of a family of manned and unmanned systems, connected by a common network. This program will allow the warfighter to dominate in complex environments and provide revolutionary levels of joint connectivity, situational awareness, and synchronized operations. FCS will utilize UGVs and UAVs for such activities as target detection, location and classification; reconnaissance, surveillance, and target acquisition; overall security information; communication relay; and early warning capabilities. FCS will utilize over eight different classes of unmanned systems and sensors in revolutionizing warfare. [1]

Another program that will benefit from collaborative behaviors is the ***All-Purpose Remote Transport System (ARTS)*** developed by AFRL. The USAF has fielded 75 ARTS for use by EOD (explosive ordnance disposal) technicians to provide a teleoperated system that can locate, remove and neutralize unexploded ordnance (UXO) and improvised explosive devices (IEDs). The ARTS consists of an operator control unit (OCU) and a modified version of a standard light construction tractor, the Posi-Track MD-70. The vehicle has a low center of gravity and light footprint which makes it ideal for its primary application area, explosive ordnance disposal.[2] Before ARTS, this dangerous mission was performed by EOD technicians combing the bombing ranges and identifying each UXO and then destroying each one in place. To improve the UXO and range clearance missions, experiments have been conducted that combine the ARTS with an unmanned aerial vehicle to provide UXO detection and aerial mapping of bombing ranges. Current research is focused on automating this process and having the UAV and ARTS collaborative to perform these missions.

The military has several programs in development designed to protect the warfighter both at home and in theater. The ***Mobile Detection Assessment Response System (MDARS)*** is a joint Army-Navy development effort to provide an automated intrusion detection and inventory assessment capability for use in Department of Defense bases and depots, such as materiel storage yards, arsenals, petroleum storage areas, airfields, rail yards, and port facilities. Autonomous UGVs patrol the site, hosting application payloads for intruder detection and assessment, barrier assessment and product assessment. ***Remote Detection, Challenge and Response (REDCAR)*** program focuses on the application of mobile unmanned ground systems to support and augment security force personnel in the perimeter defense of Air Force installations and forward deployed units. The REDCAR system and proof of concept demonstration successfully proved the utility of unmanned systems to augment the Air Force Security Forces mission. REDCAR met all the major goals including: 1) Developing a system of robotic systems with the surveillance, engagement, and small scale platforms, 2) Integrating the JAUS command and control network and common OCU, 3) Integrating the REDCAR systems with the TASS (***Tactical, Area Security System***) and 4) Demonstrating the concept to the Air Force Security Forces leadership. The REDCAR initiative was a successful collaboration between the Force Protection Battlelab, AFRL, and the many technical partners including: US Army Program Manager – Force Protection Systems (PM-FPS), SPAWAR Systems Center – Unmanned Systems Branch, and USAF Electronic Systems Center (ESC/FD). [3,4]

A third program, the ***Family of Integrated Rapid Response Equipment (FIRRE)*** is an advanced technology demonstration program intended to develop a family of affordable, scalable, modular, and logistically supportable unmanned systems to meet urgent operational force protection needs and requirements worldwide. The near-term goal is to provide the best available unmanned ground systems to the war fighter in Iraq and Afghanistan. The overarching long-term goal is to develop a fully-integrated, layered force protection system of systems for our forward deployed forces that is networked with the future force C4ISR systems architecture. The intent of the FIRRE program is to reduce manpower requirements, enhance force protection capabilities, and reduce casualties through the use of unmanned systems. FIRRE could utilize collaborative behaviors among unmanned systems to help create a portable in-theater security system that makes use of the ability to share information and make decisions among different sensors and unmanned systems according to its goals. [5]

Equipment, scenarios, plans and data from all of these individual programs will be factored into the development efforts by CEE. The goal of CEE is to demonstrate real-world collaborative capabilities that will raise the awareness of program managers, developers, and users about the capabilities and challenges of collaborative engagement involving unmanned systems.

2. CEE TECHNICAL PROGRAM GOALS

Several areas need to be addressed in order to provide a collaborative capability among unmanned systems. These include the communication link between the unmanned systems, the human operators, and the command and control system; the common protocol for connection and task coordination between unmanned systems; the OCU for human operators to monitor the status of collaborative tasks; the concept of operations (CONOPS) for collaborative systems, operational rules for deployment of munitions by unmanned systems, and the physical connections between collaborative unmanned systems (e.g. UAVs dropping UGVs or UGVs refueling UAVs).

The goal of CEE is to address some of these areas, providing a joint collaborative capability through the unification of discrete service programs. CEE is not a single demonstration; instead it is the development of an ongoing Joint partnership in order to provide a framework for evaluating and responding to emerging operational requirements in the area of unmanned systems. Each of the CEE service laboratories brings a different set of strengths and a different background to this Joint effort. These strengths are combined with an iterative process of operational/user analysis, technical development, experimentation/data collection, and evaluation. The results from each phase are fed back into the user and technical communities in order to further the goal of robust, collaborative unmanned systems for ALL services.

The CEE program will assess information requirements and conduct experiments to identify and resolve technical risks for collaborative engagements using Unmanned Ground Vehicles (UGVs) and Unmanned Aerial Vehicles (UAVs). It will research, develop and physically integrate multiple unmanned and communications systems and conduct live collaborative experiments. Modeling and Simulation systems will be upgraded to reflect engineering fidelity levels to greater understand technical challenges to operate as a team.

One of the main technology tools that CEE will utilize in collaborative experimentation is JAUS. This architecture is an upper level design for the interfaces within the domain of Unmanned Vehicles. JAUS defines messages and component behaviors that are independent of technology, computer hardware, operator use, and vehicle platforms and isolated from mission. JAUS uses the Society of Automotive Engineers Generic Open Architecture (SAE GOA) framework to classify the interfaces. It complies with the Joint Technical Architecture as well as the Joint Technical Architecture - Army. JAUS is platform and application independent and is being developed to “reduce life cycle costs, reduce development and integration time, provide a framework for technology insertion, and accommodate expansion of existing systems with new capabilities.” [6]

The JAUS messages necessary to conduct collaborative engagements will be developed by the CEE organizations and modeled providing data for operational modeling and simulation. This data will be inserted into a User conducted assessment to ascertain potential operational significance, determine possible missions and develop initial system specifications for the concept.

3. LABORATORY BACKGROUND

The mission of AMRDEC JTC/SIL is to develop & maintain a center for the development, assessment, maturation, integration, transfer, and forecasting of technologies that comprise and enhance Unmanned Systems (Robotics) operations and their performance. AMRDEC JTC/SIL is a leader in the areas of remote engagement and automated lethality, the development of the Joint Architecture for Unmanned Systems (JAUS) and the use of its Multiple Unified Simulation Environment (MUSE) for virtual unmanned systems development.

The AFRL, Force Protection Branch, Robotics Group conducts advanced research for the development of intelligent unmanned systems. The AFRL program is RACS – Robotics for Agile Combat Support with the mission to develop robotic systems and technologies for Force Protection. Primary research areas include: Advanced Robotics Technologies Development with focus on intelligent systems, and technologies for: Explosive Ordnance Disposal, Automated Range Clearance, First Responders, Aircraft and Airbase Operations Support Systems.

The Unmanned Systems Branch of SSC San Diego provides network-integrated robotic solutions for Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) applications, serving and partnering with industry, academia, and other government agencies. Through its accomplishments in the laboratory and

field, SSC San Diego was designated the Center of Excellence for Small Robots by the OSD JRP in 2002. SSC San Diego is developing C4ISR solutions for unmanned ground vehicles UGVs, unmanned aerial vehicles UAVs, unmanned surface vehicles (USVs), unattended ground sensors (UGS), and unattended munitions. [7]

4. CEE RESULTS

These are the technical accomplishments of each organization over the past year and a half that CEE has been organizing. The ultimate goal is to have integrated development among the laboratories, but due to funding constraints, the team decided to continue to develop complimentary technologies in parallel. They will be integrated into a Joint experiment as soon as funding is available.

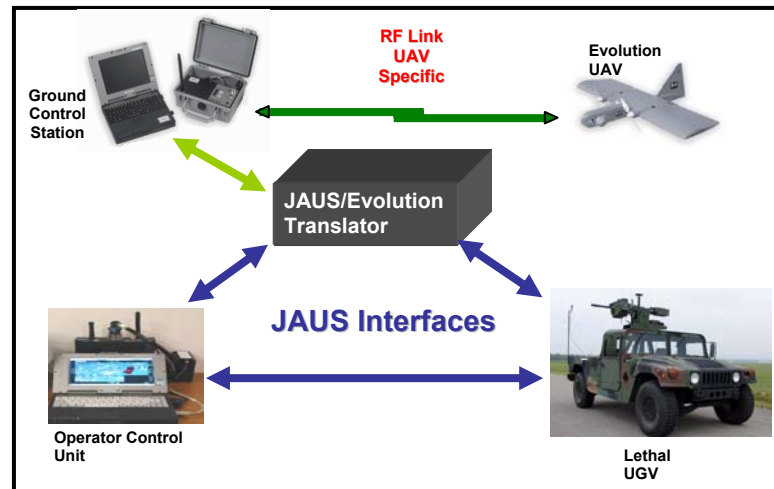


Fig. 1. AMRDEC JTC/SIL CEE

AMRDEC JTC/SIL is experimenting with collaborative JAUS messages to enable unmanned systems to collaborate effectively with minimal operator intervention. These messages will be tested in the MUSE environment with a JAUS collaborative OCU with future experimentation performed with live assets. The MUSE simulation features a UGV model based on the Marine Corps Gladiator and a UAV model based on the L-3Com/BAI Evolution. Additional development with L-3Com/BAI is being performed to enable the Evolution UAV to be controlled via a JAUS OCU for future live experimentation. Past collaborative efforts included the development of a JAUS API for use with MUSE environment, implementation of a UGV model with turret control in MUSE environment, and design and integration of a JAUS Operator Control Unit to control a simulated UGV and UAV simultaneously.

AMRDEC's work on CEE to date includes the completion of the User (Soldier Battle Lab) collaborative operation analysis, development of experimental JAUS messages for the Evolution, completion of the update of previous JAUS API to support Evolution development of JAUS/Evolution Translator with L-3Com/BAI, and development and integration of Evolution model for the MUSE simulation, update of MUSE UGV model for collision detection, and completion of test and integration of UGV model.

The JAUS collaborative messages developed for the CEE project will be tested in the CEE experiment after the completion of the following tasks:

- Complete development of JAUS/Evolution Translator
- Update of Evolution Ground Control Station software.
- Integrate JAUS/Evolution Translator with CEE OCU.
- Flight test Evolution with Translator and CEE OCU
- Analyze Collaborative operations and messages for implementation into the JAUS Message set.
- Update JAUS API for JASU collaborative messages.

- Update models of MUSE UAV and UGV with new JAUS Collaborative messages.
- Complete development of CEE Operator Control Unit (OCU).
- Integrate CEE OCU with MUSE simulation.
- Perform collaborative operations experiment with a simulated UAV and UGV system.
- Develop collaboration simulation report.

AFRL is developing a UAV/UGV communications relay system which includes a non line of sight radio frequency communications link (hardware and algorithms) between the command center and the unmanned systems including system to system links. AFRL participated with the UAV Battlelab in 2003 for the STORK project to demonstrate the concept of using a UAV to extend the communication range of a network of UGVs. The STORK project successfully extended the communications range to 26 kilometers for an 802.11 based network of unmanned systems. AFRL will use the STORK assets to continue the CEE work. These are the five major subtasks to accomplish this objective:

- Upgrade project STORK communications repeater payload with a more powerful amplifier and higher gain antennas,
- Implement a self-tracking base station antenna system,
- Integrate the communications relay payload to the AFRL RMax rotary UAV,
- Develop dynamic positioning algorithms to control the UAV's position to optimize network communications
- Develop and implement collaborative JAUS messages and system behaviors.

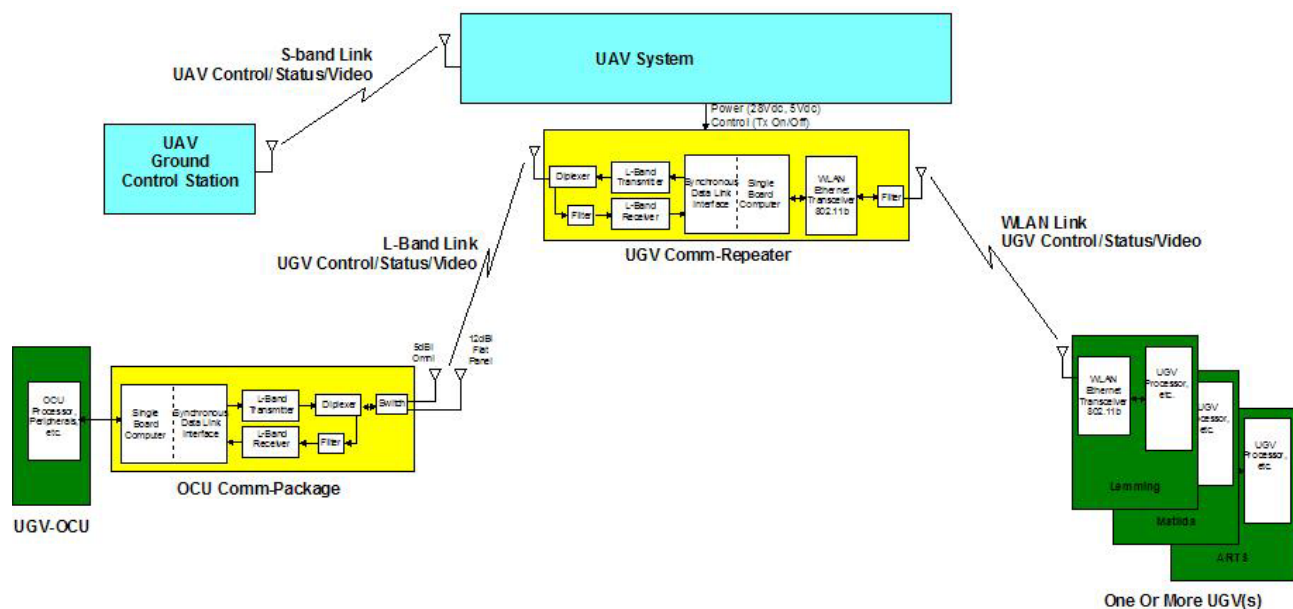


Fig. 2. Communication System Relay Block Diagram

The UAV test bed for the aerial communications relay will be the AFRL RMAX rotary wing UAV. The AFRL RMAX is a commercially available Yamaha RMAX that has been upgraded to include a GPS waypoint capable autopilot from WePilot. The RMAX will carry the communication repeater payload on its modular payload tray between the landing struts. The RMAX will monitor the communications signal strengths and position itself to optimize RF communication to the network of UGV systems as appropriate to the mission profile. This may include leader follower behaviors, optimizing communication to a single system, or optimizing communications for the whole network. The UGV test bed for this system is the AFRL SCOUT robotic ATV platform. SCOUT is a high speed engagement platform developed as part of the REDCAR initiative with the USAF Force Protection Battle Lab.



Fig. 3. AFRL REDCAR SCOUT (left) and AFRL RMAX UAV with payload (right)

Additional AFRL test bed vehicles with compatible network radios will be used as needed to fully explore the capabilities of the communications relay and its behaviors. The system experimentation and testing will be conducted at AFRL/MLQF's robotic test range located at Tyndall AFB, FL during the summer of 2006.



Fig. 4. AUMS with iSTAR UAV and MDARS

SSC San Diego has developed the Autonomous UAV Mission System (AUMS) for small Vertical Takeoff and Landing (VTOL) UAVs. This system is designed to provide forward staging, refueling, and recovery capabilities for the VTOL UAV by utilizing a host unmanned ground vehicle (UGV) to serve as a launch/landing platform and service station. AUMS is designed for use with several small VTOL UAVs including the AAI Corp's iSTAR ducted fan and the Rotomotion, LLC autonomous helicopter. The AUMS can be mounted on a UGV or a manned vehicle and can be used as a fixed station located around the perimeter of a secure area. SSC San Diego is working with small VTOL UAV manufacturers as well as universities to develop precision landing capabilities for re-landing the UAVs on the AUMS.

The AUMS system is compliant with JAUS and utilizes the Multi-Robot Operator Control Unit (MOCU) software developed by SSC San Diego for C2 interface to a human operator (Fig. 5). MOCU is also a JAUS compliant system designed specifically for the purpose of controlling multiple heterogeneous unmanned systems simultaneously. MOCU has been utilized for the control of multiple UGVs of various sizes including MDARS as well as much smaller man-portable systems, several USVs, and most recently a VTOL UAV. It also is capable of controlling and collecting data from a wide variety of stationary unmanned systems and sensors including remotely operated weapons systems, radars, video systems, and seismic detectors. The MOCU graphical user interface can automatically configure itself appropriately for the vehicle, system, or sensor being queried at a given time. [8]

AUMS represents a key technology area for CEE, demonstrating collaborative behaviors between UGVs and UAVs while fulfilling an operational need by enhancing the operational capabilities of small VTOL UAVs. The AUMS will be showcased in several demonstrations in 2006, including the FIRRE program evaluation in August at the Yuma Proving Grounds.



Fig. 5. UAV view in MOCU

5. SOLDIER BATTLE LAB ANALYSIS

The CEE program has begun work on an operational analysis of both current and future user requirements involving unmanned systems. The Soldier Battle Lab at Fort Benning conducted a task analysis to determine the impact that collaborative engagement technologies could have on the makeup of a mission. The analysis has identified numerous Infantry missions where robotic assets could play a significant role in assisting the Infantry achieve its stated objective. The analysis has also found that the Infantry Platoon is not sufficiently resourced with the personnel to dedicate an operator for each of its robotic systems. Without these platforms achieving a high degree of collaborative and adaptive behaviors they will quickly become more of a burden than a benefit. This burden cannot monopolize the Soldier's focus and cognitive workload, or impede the accomplishment of the basic Soldier's mission: to close with and kill the enemy.

The mission of the United States Army's Soldier Battle Lab is to support the Army's Vision and Transformation goals by conducting constructive, virtual, and/or live experiments. These experiments are used to gain insights, impacts, and to recommend changes to Doctrine, Training, Leader Development, Organization, Material, Personnel and Facilities, based on inputs from soldiers and their leaders, as well as emerging technologies and materiel initiatives to support the Current and Future Force.

The modern battlefield possesses qualities today that are unprecedented. Soldiers face asymmetric threats that are constantly changing shape, shifting and molding themselves to gain what little advantage their disposition will allow. Our country's enemies have realized that the United States possesses the tactical and technological advantage. They recognize that U.S. forces are well organized, well equipped, well trained, and are capable of crushing them quickly in a traditional face-to-face confrontation.

Large UAVs have been circling the skies of Iraq, Afghanistan, and other parts of the world for years. They have collected invaluable intelligence, pinpointed our enemies, and in some cases ruthlessly destroyed them as they planned our demise. Small UAVs and some ground robotic platforms are starting to bring the same benefits to small units. These platforms are providing leaders at the Battalion level and below unprecedented situational information and allowing them to take that information to develop operational plans that are much more effective and feasible. The efficient employment of battlefield robotic assets will soon be much more challenging. The Army's FCS introduces a number of

new platforms, each bringing a unique set of controllers, accessories, and training and employment requirements. With FCS however, come challenges. If these platforms are not capable of highly collaborative and adaptive behaviors they will quickly become more of a burden than a benefit. Unmanned Systems are now becoming more prevalent in Today's Fighting Force.

In the FCS Unit of Action (UA), Unmanned Systems are an integral part of the Force. Each UA Infantry Company will have 3 Armed Robotic Vehicles (Assault), 3 Class I UAV systems (6 AVs), 3 Class II UAV systems (3 AVs), and 9 Small UGVs. With a total of 18 Unmanned systems in every UA Infantry Company, the key question is "Who will operate all of these systems?" Which member of the Squads and Platoons can focus their efforts on controlling an UMS and *NOT* on closing with and killing the enemy? The answer of course is No One!

Collaboration and autonomy of UMSs is a necessity. The current Infantry Platoon consists of a Platoon Headquarters, three Infantry Squads and a Weapons Squad. The Infantry Squad consists of nine personnel, the squad leader and two 4-man fire teams. Each 4-man fire team consists of a team leader, grenadier, and an automatic rifleman. The fourth man within each team is either the squad's anti-tank specialist or the squad's designated marksman. Each weapons squad consists of a squad leader and two 3-man machine gun teams. A machine gun team consists of the gunner, the assistant gunner and the ammo bearer. The average skill level 1 Infantry Soldier must be proficient in 100+ individual tasks just to perform his basic infantry mission. [9]

The number of individual tasks increases to 200+ for Skill Level 2-4 Soldiers. The average Signal Soldier must be proficient in 63 tasks just to perform his basic signal mission. These 63 tasks do not include other additional common soldier skills he is responsible for. [10, 11]

Robotic assets are beginning to play a more significant role on today's battlefields. Small UGV's have been used successfully to clear caves in Afghanistan and bunkers and buildings in Iraq. These operations have saved countless Soldiers' lives. However, in all these operations, the robotic assets were controlled by an operator manning an Operator Control Unit somewhere in the background.

As part of the CEE effort, the Soldier Battle Lab conducted a task analysis to determine the impact that collaborative engagement technologies could have on the makeup of a mission. Our task analysis has identified numerous Infantry missions where robotic assets could play a significant role in assisting the Infantry achieve its stated objective (Fig. 6). Our analysis has also found that the Infantry Platoon is not sufficiently resourced with the personnel to dedicate an operator for each of its robotic systems. Without these platforms achieving a high degree of collaborative and adaptive behaviors they will quickly become more of a burden than a benefit. This burden cannot monopolize the Soldier's focus and cognitive workload, or impede the accomplishment of the basic Soldier's mission: to close with and kill the enemy.

Collective Task	Task No.	Echelon
Conduct Convoy Escort	07-3-1225	Platoon/ Squad
Conduct a Route Reconnaissance	07-3-2000	Infantry/ Reconnaissance Platoon/ Squad
Conduct a Movement to Contact	07-3-1090	Infantry/ Reconnaissance Platoon/ Squad
Reconnoiter a Built-up Area	07-3-2036	Infantry/ Reconnaissance Platoon/ Squad
Assault a Building	07-3-1000	Infantry Platoon/ Squad
Breach an Obstacle	07-3-1027	Infantry Platoon/ Squad
Conduct a Defense	07-3-1054	Infantry Platoon/ Squad
Conduct Tactical Movement in a Built-up Area	07-3-1279	Antiarmor/ Infantry/ Reconnaissance Platoon/ Squad
React to Civil Disturbance	07-3-1396	Antiarmor/ Infantry/ Reconnaissance Platoon/ Squad
React to Snipers	07-3-1406	Infantry/ Reconnaissance Platoon/ Squad
Search a Building	07-3-1432	Infantry Platoon/ Squad
Conduct Consolidation and Reorganization	07-3-5009	Infantry/ Reconnaissance Platoon/ Squad
Occupy an Assembly Area	07-3-5063	Infantry/ Mortar/ Reconnaissance Platoon/ Squad
Conduct a Presence Patrol	07-3-1117	Antiarmor/ Infantry/ Reconnaissance Platoon/ Squad

Fig. 6. Tasks from Infantry Soldier's Manual (STP7-11B1-SM-TG)

Here's an example of how one task can benefit from collaborative unmanned systems.

Assault a Building- 07-3-1000. An assault is an offensive operation undertaken to destroy the enemy and his will to fight; to seize terrain; to learn enemy strength and disposition; or to deceive, divert, or fix the enemy. Infantry platoons and squads normally conduct offensive operations as part of a larger force. However, they can perform some offensive operations independently. Offensive operations are characterized by flexibility, surprise, concentration, speed and audacity.

Planning Phase:

In the current task description for "Assault on a Building" the members of the platoon plan the task using various sources of information about the building they are about to assault. This information is gathered from force XXI battle command brigade and below (FBCB2) if available, FM comms, maps, intel summaries, SITREPs, and or other available information sources. The data may be hours or even days old and the entire mission strategy is developed around this information. The platoon leader must make a decision to accept the information as given or send additional personnel into the area for an 'eyes on target' initiative to gather more recent data. This increases the risk to human life and reduces personnel available for other mission planning tasks.

In an alternate scenario, the Platoon Leader utilizes unmanned systems to conduct reconnaissance for the assault. The Platoon leader surveys the route/objective with a Class I/II UAV and Armed Robotic Vehicle-Reconnaissance, Surveillance and Target Acquisitions (ARV-RSTA), Mission, Enemy, Terrain and Weather, Troops and Support Available, Time Available and Civilian Considerations (METT-C) dependent. The reconnaissance identifies rally points,

support by fire positions, avenues of approaches, assault positions etc. The use of unmanned systems will increase the real-time availability of information as well as reduce the risk to personnel. The increased availability of personnel for the core mission tasks will enable more technical experts at the mission level.

Execution Phase:

During the execution phase a platoon member is usually designated to provide overwatch and observe the breach and assault elements in order to provide feedback to the platoon leader. The use of human resources to provide real-time monitoring reduces the manpower available for the highly technical tasks involved in assaulting a building. This can add risk to the mission, reducing the effectiveness.

Alternatively, Armed Robotic Vehicle-Assault (ARV-A)/ARV-RSTA and Class I/II UAVs could provide security and surveillance during movement to the objective. The Class I/II UAV would fly ahead of assault force at a preset interval and provide real-time SA to platoon leader. Cross-cueing of air and ground assets would allow ground assets to move up to take closer look at an obstacle or other Named Areas of Interest (NAIs). At the objective, the Class II UAV could perform hover and stare mission to provide SA, while the ARV-RSTA/ARV-A could provide overwatch or flank security. The SUG-V could provide assistance to breaching element by reconnoitering breaching sites. Once breaching element has secured a foothold for the assault element, the SUGV could provide firsthand SA of the breaching site. The Class I UAV could provide additional SA of the objective and provide targeting data to the either manned or unmanned system. This would free up personnel and increase effectiveness of the mission.

6. CONCLUSIONS AND FUTURE PLANS

The nature of warfighting is changing and unmanned ground and air systems operating in collaboration have the potential to provide future Joint Forces a significant capability for operations in complex terrain. As the military develops more unmanned systems, the need for collaboration between these systems will increase. The Joint Collaborative Engagement Experiment brings together the Army, Navy, and Air Force to research, develop, and integrate the key technology pieces that will enable unmanned systems to perform collaboratively while increasing their effectiveness and reducing the burden on the warfighter.

CEE's goal of demonstrating real-world collaborative capabilities will raise the awareness of program managers, developers, and users about the capabilities and challenges of collaborative engagement involving unmanned systems. CEE provides a framework for evaluating feedback and information from users and feeding that back into technology development processes as part of a Joint effort with service laboratories. CEE's Joint experimentation is currently limited by funding shortfalls, but as individual technology efforts move forward, great audiences will have the chance to see the potential capabilities and invest in the bringing future ideas to today's battlefield.

ACKNOWLEDGEMENTS

This work was supported by the Office of the Secretary of Defense under the direction of the Joint Robotics Program.

REFERENCES

1. PROGRAM MANAGER – UNIT OF ACTION, "Future Combat Systems: 18+1+1 Systems Overview", September 29, 2005, URL: [http://www.army.mil/fcs/whitepaper/FCSWhitePaper\(v19_29Sep05\).doc](http://www.army.mil/fcs/whitepaper/FCSWhitePaper(v19_29Sep05).doc) (Accessed March 29, 2006)
2. WALTZ, WALTER (AFRL) and TIMOTHY ANDERL (Anteon Corporation), "All-Purpose Remote Transport System", AFRL's Materials and Manufacturing Directorate, Airbase Technologies Division, Force Protection Branch, Tyndall AFB FL, June 2003, <http://www.afrlhorizons.com/Briefs/Jun03/ML0301.html> (Accessed April 14, 2006)
3. SHOOP, B.P., JOHNSTON, M. L., GOEHRING, R. H., AND J.C. MONEYHUN, "Mobile detection assessment and response system: a force protection physical security operational success," SPIE Proc. 6230: Unmanned Systems Technology VIII, Defense Security Symposium, Orlando, FL, April 18-20, 2006.
4. Remote Detection, Challenge, and Response System (REDCAR), Global Security website, URL: <http://www.globalsecurity.org/military/systems/ground/redcar.htm> (Accessed April 14, 2006)

5. CRUICKSHANKS, J., KRAMER, T., LAIRD, R., THOMAS, K. and J. MONEYHUN, "FIRRE command and control station", Unmanned Systems Technology VIII , SPIE Defense and Security Symposium, Orlando, FL, April 17-21, 2006.
6. Joint Architecture for Unmanned Systems Website, URL: <http://www.jauswg.org> (Accessed April 14, 2006)
7. Robotics at Space and Naval Warfare Systems Center San Diego, URL: <http://www.spawar.navy.mil/robots> (Accessed April 14, 2006)
8. Bruch, M. H., "The multi-robot operator control unit (MOCU)," SPIE Proc. 6230: Unmanned Systems Technology VIII, Defense Security Symposium, Orlando, FL, April 18-20, 2006.
9. United States Army, "Soldier's Manual 11-B Infantryman", July 1985 (STP7-11B1-SM)
10. Soldier's Manual and Trainer's Guide, MOS 11B, Skill Levels 2,3 and 4. (STP-11B24-SM-TG)
11. TRADOC Pamphlet 525-3-90 O&O, The US Army Future Force Operational and Organization Plan Maneuver Unit of Action (C4 NCO-25U20)